APPLICATION FOR UNITED STATES PATENT

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Title: **MAGNIFICATION VIEWER**

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MAGNIFICATION VIEWER

This application is a divisional of Application Serial No. 09/761,086 filed January 15, 2001 (now pending) which is a continuation of Application Serial No. 09/062,936 filed April 20, 1998, now U.S. Patent No. 6,201,640, the disclosure of which is fully incorporated herein by reference.

Field of the Invention

The present invention relates to magnification viewers worn by surgeons and dentists. In particular, the invention relates to an assembly for optical views or loupes which allow a user to adjust an objective lens at a predetermined distance from an eyepiece lens to vary the focal point.

Background of the Invention

Magnification viewers, including, but not limited to, pairs of magnification loupes, are worn by dentists and surgeons for extended periods of time during clinical procedures. These viewers are worn to provide clarity of view while avoiding a hunched-over position that can result over time in debilitating neck and back strain, which can also have an adverse effect on the success of the operation. The viewers permit the clinician to operate at a greater working distance from the patient. Higher magnification viewers also reduce the clinician's exposure to aerosols.

Because clinicians use magnification viewers during surgery and other procedure requiring manual precision, it is important that the viewers be light-weight, comfortable and have good clarity and wide field of vision while providing high magnification and good depth of field.

Surgical telescopes may be attached to a spectacle frame in one of two manners: outside-the-carrier or prescription lens ("outside-the-lens"), on an adjustment mechanism that provides for adjustment of the interpupillary distance and convergent angle variability, or through-the-lens, permanently cemented and fixed in place. Magnification viewers used by surgeons and dentists typically have a predetermined magnification. Neither the working distance nor the magnification may be changed without a tedious process of replacing either individual lens elements or the entire optical loupes themselves. Accordingly, there is a need for a simple method for changing the magnification of viewers being worn by a surgeon or dentist, as well as for altering the working distance of viewers having a particular magnification.

Summary of the Invention

In accordance with one embodiment of the invention, a housing for a magnification loupe is provided having an eyepiece portion for an eyepiece lens and a nose portion for an objective lens. The body portion for the eyepiece lens includes outer circumferential threads over which the objective nose portion fits. The objective nose portion includes a pair of apertures for receiving a pin. The apertures are configured such that the pin forms a chord across the body of the nose portion and co-acts with the

threads of the eyepiece body forming an axial mechanical stop to prevent the nose portion from being removed during adjustment.

Magnification loupes, according to the present invention, include a nose housing for an objective lens and a body housing for an eyepiece lens. The system is configured such that the magnification of the magnification loupe may be changed simply by removing the nose housing and replacing it with another. The working distance for a particular magnification level may be adjusted by threading or unthreading the nose housing.

Brief Description of the Drawings

A better understanding of the present invention is obtained when the following detailed description is considered in conjunction with the following drawings in which:

FIGS. 1A-1C are perspective views of a magnification loupe in accordance with the present invention illustrating the connection of a pair of magnification loupes according to an embodiment of the present invention secured through the lenses of a pair of spectacles forming a magnification viewer in accordance with the present invention;

FIG. 2 is a perspective view of magnification loupes according to the present invention secured to an adjustable nose piece for securing to a pair of spectacles;

FIG. 3A is an exploded perspective view of the magnification loupes assembly for the magnification loupes of FIGS. 1 and 2;

FIG. 3B is a side cross-sectional view of the magnification

loupe of FIG. 3A;

FIG. 4 is a side-elevation view of a nose housing forming a portion of the magnification viewers of FIGS. 1 and 2;

FIGS. 5A and 5B are side cross-sectional views and detail side cross-sectional views, respectively, of the housing of FIG. 4;

FIG. 6 is a top plan view of the nose housing of FIGS. 4 and 5;

FIG. 7 is a side elevational view of the eyepiece housing of FIGS. 1 and 2;

FIGS. 8A-8C are side cross-sectional views of the housing of FIG. 7, including details thereof;

FIG. 9 is a top plan view of the eyepiece housing of FIGS. 7 and 8;

FIG. 10 is a side elevational view of a spacer for the magnification loupes of FIGS. 1 and 2;

FIG. 11 is a side cross-sectional view of the spacer of FIG. 10;

FIG. 12 is a top elevational view of the spacer of FIGS. 10 and 11;

FIG. 13 is a side elevational view of a field stop of the magnification viewer of FIGS. 1-3;

FIG. 14 is a side cross-sectional view of the spacer of FIG. 13;

FIG. 15 is a top plan view of the spacer of FIGS. 13 and 14;

FIG. 16 is a side elevational view of an objective lens retainer ring of the magnification loupes of FIGS. 1-3;

FIG. 17 is a side cross-sectional view of the objective retainer

of FIG. 16;

FIG. 18 is a top plan view of the objective retainer of FIGS. 16 and 17;

FIGS. 19A and 19B are exploded perspective views of a prism assembly for the magnification loupes of FIGS. 1-3;

FIGS. 20A, 20B and 21-22 illustrate a prism for the prism assembly of FIGS. 19A and 19B;

FIGS. 23-26 illustrate the prims assembly of FIG. 19;

FIGS. 27-29 illustrate the roof prism of the prism assembly of FIG. 19;

FIGS. 30-32 illustrate the second prism of the prism assembly of FIG. 19;

FIG. 33 is a diagram of the optical layout of the magnification loupe of FIG. 31; and

FIG. 34 is an optical layout diagram of the optical loupe of FIG. 31, according to an alternate embodiment.

Detailed Description

Turning now to the drawings and with particular attention to FIG. 1, a magnification viewer 10 including a pair of spectacles 100 with through-the-lens magnification loupes 106a, 106b. As illustrated, the magnification loupes 106a, 106b are of the Keplerian design. The spectacles 100 include carrier lenses 102a, 102b. The carrier lenses 102a, 102b may be either plano lenses or prescription lenses. The magnification loupes 106a, 106b are fixed in the carrier lenses 102a, 102b to provide

stereoscopic vision. The magnification loupes 106a, 106b are set at the user's interpupillary distance converging to a desired working distance, for example, anywhere from 12 to 24 or 13 to 21 inches. As will be discussed in greater detail below, from a selected working distance, the user has the option to vary the viewing distance by rotating the objective lens housing or nose housing 108a, 108b of each magnification loupe 106a, 106b to the desired focus. As will be discussed in more detail below, one of the objective lens housings 108a, 108b and one of the eyepiece housings 110a, 110b are formed with threads, which cooperate with a pin attached to the other housing to form a threaded coupling. The eyepiece housings, 110a, 110b, in turn, are secured to the carrier lenses 102a, 102b by various techniques, including a friction fit or with an adhesive, such as epoxy. Alternatively, the eyepiece housings 110a, 110b may be secured to the carrier lenses 102a, 102b by way of known threading on the outside of the eyepiece housings 110a, 110b matching threading on the carrier lenses 102a, 102b.

As will be discussed in greater detail below, magnifications of 3.3x, 3.8x, 4.3x and 4.8x are possible, according to one embodiment of the invention to provide a wide range of selection. For each magnification, working distances of about 12", 16" and 24" may be provided. The carrier lenses 102a, 102b normally enable a user to focus comfortably at 500 mm, about -2D, a typical reading distance. The magnification loupes 106a, 106b, as will be discussed in greater detail below, further include a prism system (FIG. 19-32). Each magnification loupe uses an identical prism and

eyepiece lens system. For different magnifications, only the objective lenses are changed. The user may create depth of field by adjusting the focal distance of each eye depending upon the operation being performed. the focuses of each of the magnification loupes 106a, 106b may be changed independently. The aperture for the objective lens has been reduced in size to provide an increase in depth of field at high magnifications while still providing substantial light.

Turning now to FIG. 2, an alternative configuration of the magnification loupes 106a, 106b of FIG. 1 is illustrated. It is noted that for the lens system 20 of FIGS. 2, the optical configurations of the magnification loupes 206a, 206b are different from the through-the-lens configuration of FIG. 1, but the barrels or housings are similar in that only the objective lens need be changed to provide different magnifications. The prism and eyepiece remain the same. The optical system 20 of FIG. 2 includes a pair of spectacles 200 including a pair of carrier lenses 202a, 202b and a binocular magnification viewer 25, including a pair of magnification loupes 206a, 206b. As discussed in U.S. Patent No. 5,667,291, the binocular magnification viewer 25 may be attached to the spectacles 200 by a pivot member 250. Alternatively, the magnification loupes 206a, 206b, may be mounted close to the spectacle lenses, for example, about 0.5 mm from the carrier lenses 202a, 202b. The pivot member 250, in turn, is attached to a bridge 258 which includes a bridge adjustment knob 252 for adjusting a pair of extension of arms 254, 256 to enable the interpupillary distances of the loupes 206a, 206b to be adjusted.

The interpupillary distance of the magnification loupes 206a, 206b may further be adjusted by knobs 260a, 260b. The binocular magnification viewer 25 may be secured to the spectacles 200 by way of a clip, screws, glue or other known methods.

Mechanical Characteristics

Turning now to FIG. 3A, an exploded perspective view of the magnification loupes 106 in accordance with the present invention are shown. For the purposes of this discussion, only one of the magnification loupes 106 and its components shall be discussed. It is understood, however, that all descriptions are equally applicable to loupe 106b and its components. The magnification loupes 106a include a nose or objective housing 108a and a body or eyepiece housing 110a. As illustrated, the objective housing 108a includes a frusto-conical front portion 350 and a generally cylindrical rear portion 352. It is noted that the housing 108a may be of different shapes; thus, FIG. 3 is exemplary only. The objective housing 108a includes a pair of apertures 304. The apertures 304 are configured to receive a pin 302 such that the pin 302 defines a chord across the cylindrical rear portion 352 of the objective housing 108a. More particularly with reference to FIG. 3B, the objective housing 108a includes an interior surface 308 which engages an exterior surface 307 of the eyepiece housing 110a. Spiral threads 306 are formed into the surface of the eyepiece housing 110a. The apertures 304 are located in the objective housing 108a so that the pin 302 engage the spirals or threads 306. The pin 302 enables a threaded coupling between the two housings 106a and

108a even through only one housing 110a is formed with threads. The threaded coupling between the housings 106a and 108a permits the working distance of the loupes 106a and 106b to be adjusted by rotating the objective housing 108a relative to the eyepiece housing 110a, which in turn, varies the distance between the eyepiece and objective lenses which varies the working distance between the loupes 106a and 106b.

Another important aspect of the invention is that the configuration allows the magnification of the loupes 106a and 106b to be rather easily changed. More particularly, the pin 302 may be removably mounted relative to the objective housing 108a or fixedly mounted with the use of epoxy. Depending on the embodiment, the magnification of the loupe can be rather easily changed at the factory or by the user, or both. In particular, as will be discussed in more detail below, the magnification of the loupe 106a is changed simply by changing the objective lens in the loupe 106a. The objective lenses are easily changed by removing the pin 302 which enables the objective housing 108a to be removed so that the objective lens 312 can be removed and replaced. As will be discussed in more detail below, an important aspect of the invention relates to the ability to vary the magnification of the loupe 106a.

As best illustrated in FIGS. 3A and 3B, the objective lens 312 is configured to rest within a first interior portion 360 of the objective housing 108a. The interior portion 360 includes a circumferential slot 311 for seating an O-ring 310 therein. The objective lens 312 rests against the O-ring 310 and is engaged in place by a threaded retainer ring 314. The

retainer ring 314 includes external threads to engage corresponding threads on the interior portion 360 of the objective housing 108a.

Additional details concerning the objective housing 108a are illustrated in FIGS. 4-6. For example, the exterior of the objective housing 108a may include a knurled portion 109 for easy engagement of the objective housing 108a to the eyepiece housing 110a.

The eyepiece housing 110a, illustrated in greater detail in FIGS. 7-9, includes a forward engagement portion 307 and a rear cylindrical portion 309. As discussed above, the forward engagement portion 307 includes threads 306 for engagement with the pin 302. It is noted that according to one embodiment of the invention, the threads 306 are circular threads rather than notched or V-shaped threads so as to more effectively engage the pin 302. The eyepiece housing 110a includes internal threads 340 positioned where the engagement housing 307 meets the rear cylindrical portion 309. The threads 340 are configured to engage the threads 341 of the field stop 318 (figs. 3A, 3B). The rear cylindrical portion 309 of the eyepiece housing 110a further includes a circumferential platform 344, configured to receive a lens 332, for example, a prescription lens. The lens 332 is held in place against the platform 344 in contact with a prescription lens O-ring 340 and a retainer ring 334, which has external threads that engage the internal threads 342 of the eyepiece housing 110a. In the embodiment illustrated, the rear cylindrical portion 309 of the housing 110a is configured to be fastened to the carrier lens 102a by way of a suitable adhesive, such as epoxy. In an alternative embodiment,

however, the rear cylindrical portion 309 may be provided with threads to engage similar threads in the carrier lens.

The forward engagement portion 307 of the eyepiece housing 110a is further configured to receive a prism assembly 316 (FIGS. 19A, 19B). The prism assembly 316 includes a prism holder 317 including a pair of arms 319a, 319b, a base portion 321, and is adapted to fit within the housing 110a. The forward portions of the arms 319a, 319b include circular cutout portions 323a, 323b, respectively, to engage a holder ring 402. The holder ring 402 is configured, when attached in place (such as by an adhesive), to secure the prism elements 404, 406, 408. According to one embodiment, the prism elements (FIGS. 20a-22) form a roof-pechan prism separated by a spacer 408. The spacer 408 is formed, for example, of a blackened ridge metal with a six millimeter diameter hole centered on the optical axis. The prism surfaces on opposite sides of the spacer are generally parallel. The individual elements of the roof pechan prism 404, 406 are illustrated in FIGS. 23-27 and 28-30, respectively. The prism elements are formed from Schott BAK4 or LAK10 glass.

Turning back to FIGS. 3A-3B, the base of the prism assembly 316 is configured to rest against a rear wall 351 of the forward engagement portion 307 at approximately the position where it engages the rear cylindrical portion 309. A field stop 318 (FIGS. 13-15) having external threads 341 engages the corresponding internal threads 340 of the housing 110a. The field stop 318 further includes internal grooves 343. The rear cylindrical portion 309 of the housing 110 further houses the eyepiece lens

elements. As shown, the eyepiece lens includes elements 320 and 324, separated by a spacer 322. The spacer 322 is illustrated in FIGS. 10-12 and may include internal concentric grooves 329 which form a light baffle. Finally, the eyepiece lens 324 rests against the platform 344.

The exterior of the engagement housing 307 includes a pair of concentric circumferential grooves 325, 327 configured to receive the O-rings 326, 328, respectively. The O-rings 326, 328 additionally function to self-center the objective housing 108a and hence, the objective lens 312 relative to the eyepiece housing 110a.

While the configuration described and shown with regard to FIGS. 3A-3B relates to a through-the-lens viewer, a similar configuration may be used in the outside-the-lens system shown in FIG. 2. Such a system may be used without a prescription lens and, as will be described in greater detail below, a different eyepiece system.

Optical Characteristics

Turning now to FIG 33, a diagram illustrating the optical layout of the magnification loupe 106a of FIGS. 1 and 3A, 3B is shown. The magnification loupe 106a as illustrated in FIG. 33 includes a two-element objective lens including elements I-II and including a three-element eyepiece including elements III-V. R1, R2 etc., represent the radii of respective refractive surfaces; S1-S5 represent the thickness of the air spaces; and T1, T2, etc., represent the thicknesses of the lens elements. As discussed above, according to one embodiment of the invention, magnifications of 3.3x, 3.8x, 4.3x and 4.8x are provided. All magnifications use the same

prism and eyepiece lens system. As shown in FIGS. 28 and 32, the prior angle $\propto$ may be used in the range 45°- 49°, preferably 48° to increase the optical performance of the device while the prism angle B (FIG. 32) may be selected to be 24°. Thus, a common eyepiece housing 110a and optical elements included therein may be used for all of the magnifications. As discussed above, only the objective lens needs to be changed in order to alter the magnification.

The user may create a depth of field by adjusting the focal distance of each eye differently depending on the operation being performed. For example, a heart surgeon may wish to view the entire depth of the heart at high magnification previously unattainable in conventional magnification systems where depth of field is limited. This can be accomplished by adjusting the focus of the left eye one-inch beyond the right. When both eyes are then opened, the heart can be viewed in its entirety. However, a dentist may only require the depth of the coronal portion of the tooth to be in focus and thus would only separate the focus by a millimeter or two. Alternatively, both magnification loupes can be precisely focused at the same distance for procedures requiring the highest resolution. The following exemplary fields of view may be provided:

93 m @ 3.3x @ 16" WD

82 m @ 3.8x @ 16" WD

72 m @ 4.3x @ 16" WD

65 m @ 4.8x @ 16"WD

Exemplary construction data for a magnification loupe built according to the embodiment shown in FIGS. 1-3 are given in Tables I-XII. The radii, thickness, and separation dimensions are given in millimeters. Roman numerals identify the lens elements in their respective order from the objective side to the eyepoint side; n_d represents the refractive index of each element; v_d is the abbe dispersion number; R1, R1, etc., represent the radii of the respective refractive surfaces in order from the objective side to the eyepoint side; T1, T2, etc., represent the thicknesses of the lens elements from the objective side to the eyepoint side; S1, S2, etc., represent the thicknesses of air spaces respectively from the objective side to the eyepoint side measured along the optical centerline. Again, it is noted that the prism/objective distance can differ by about 2.5 mm if BAK4 glass is used, rather than LAK10, as in the tables.

FIG. 34 illustrates an embodiment of the present invention having long eye relief characteristics. Again, the system shown in FIG. 34 employs the same prism and eyepieces, but separate objective doublets for each level of magnification. The objective doublets and the prism, however, are the same as for the through-the-lens embodiment shown in FIG. 33. Additionally, only the eyepiece lens is changed from the through-the-lens configuration. As compared the embodiment of FIG. 33 eye relief (the distance to exit pupil) has been improved from about 17.8 mm to about 22.8 mm.

In particular, the viewer according to FIG. 34 includes the two-element or doublet objective including elements I-II and a four-element

eyepiece lens including elements III-VI. R1, R2, etc., again represent the radii of respective refractive surfaces; S1, S2, etc., represent the thicknesses of the air spaces; and T1, T2, etc., represent the thicknesses of the lens elements.

Exemplary construction data for loupes according to the embodiment of FIG. 34 are given in Tables XIII-XXIV.

TABLE I

3.3X
(12" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 6.96$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE II

3.3X
(16" WD)

Element	Glass	nd	νd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 5.01$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE III

3.3X
(24" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 3.63$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE IV

3.8X
(12" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.04$ $R_2 = 14.61$	4.0	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 14.61$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 12.38$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE V

3.8X
(16" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.04$ $R_2 = 14.61$	4.0	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 14.61$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 9.92$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE VI

3.8X
(24" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.04$ $R_2 = 14.61$	4.0	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 14.61$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 8.02$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE VII

4.3X
(12" WD)

Element	Glass	nd	νd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 50.15$ $R_2 = 16.00$	4.0	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 16.00$ $R_3 = 47.79$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 18.07$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE VIII

4.3X
(16" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 50.15$ $R_2 = 16.00$	4.0	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 16.00$ $R_3 = 47.79$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 15.56$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE IX

4.3X
(24" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 50.15$ $R_2 = 16.00$	4.0	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 16.00$ $R_3 = 47.79$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 13.13$ $S_2 = 3.41$ $S_3 = 7.04$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.05$ $S_5 = 17.86$
III	Ohara PBH6W	1.8052	25.4	$R_3 = 44.00$ $R_4 = 13.00$	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	$R_5 = 13.00$ $R_6 = 13.00$	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	$R_7 = 15.59$ $R_8 = 94.04$	3.0	15.4	

TABLE X

4.8X
(12" WD)

Element	Glass	nd	*v*d	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	61.12	4.0	13.4	
II	Ohara SFL6	1.8052	25.4	16.98	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 25.16 S_2 = 3.41 S_3 = 7.04
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.05 S_5 = 17.86
III	Ohara PBH6W	1.8052	25.4	R_3 = 44.00 R_4 = 13.00	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	R_5 = 13.00 R_6 = 13.00	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	R_7 = 15.59 R_8 = 94.04	3.0	15.4	

TABLE XI

4.8X
(16" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	61.12	4.0	13.4	
II	Ohara SFL6	1.8052	25.4	16.98	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 21.23 S_2 = 3.41 S_3 = 7.04
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.05 S_5 = 17.86
III	Ohara PBH6W	1.8052	25.4	R_3 = 44.00 R_4 = 13.00	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	R_5 = 13.00 R_6 = 13.00	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	R_7 = 15.59 R_8 = 94.04	3.0	15.4	

TABLE XII

4.8X
(24" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	61.12	4.0	13.4	
II	Ohara SFL6	1.8052	25.4	16.98	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 18.22 S_2 = 3.41 S_3 = 7.04
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.05 S_5 = 17.86
III	Ohara PBH6W	1.8052	25.4	R_3 = 44.00 R_4 = 13.00	2.0	15.4	
IV	Ohara FSL5	1.4875	70.2	R_5 = 13.00 R_6 = 13.00	6.5	15.4	
V	Ohara BAH10	1.6700	47.3	R_7 = 15.59 R_8 = 94.04	3.0	15.4	

TABLE XIII

3.3X
(12" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	R_1 = 42.19 R_2 = 12.45	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	R_2 = 12.45 R_3 = 36.00	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 6.96 S_2 = 3.41 S_3 = 2.33
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.5 S_5 = 22.8
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO R_5 = 12.61	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	R_5 = 12.61 R_6 = 12.61	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	R_7 = 10.06 R_6 = 12.61	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	R_8 = 25.11 R_9 = 25.11	4.7	17.5	

TABLE XIV

3.3X
(16" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	R_1 = 42.19 R_2 = 12.45	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	R_2 = 12.45 R_3 = 36.00	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 5.1 S_2 = 3.41 S_3 = 2.33
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.5 S_5 = 22.8
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO R_5 = 12.61	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	R_5 = 12.61 R_6 = 12.61	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	R_7 = 10.06 R_6 = 12.61	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	R_8 = 25.11 R_9 = 25.11	4.7	17.5	

TABLE XV

3.3X
(24" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 3.63$ $S_2 = 3.41$ $S_3 = 2.33$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.5$ $S_5 = 22.8$
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO $R_5 = 12.61$	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	$R_5 = 12.61$ $R_6 = 12.61$	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	$R_7 = 10.06$ $R_6 = 12.61$	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	$R_8 = 25.11$ $R_9 = 25.11$	4.7	17.5	

TABLE XVI

3.8X
(12" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 12.38$ $S_2 = 3.41$ $S_3 = 2.33$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.5$ $S_5 = 22.8$
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO $R_5 = 12.61$	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	$R_5 = 12.61$ $R_6 = 12.61$	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	$R_7 = 10.06$ $R_6 = 12.61$	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	$R_8 = 25.11$ $R_9 = 25.11$	4.7	17.5	

TABLE XVII

3.8X
(16" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	R_1 = 42.19 R_2 = 12.45	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	R_2 = 12.45 R_3 = 36.00	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 9.92 S_2 = 3.41 S_3 = 2.33
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.5 S_5 = 22.8
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO R_5 = 12.61	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	R_5 = 12.61 R_6 = 12.61	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	R_7 = 10.06 R_6 = 12.61	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	R_8 = 25.11 R_9 = 25.11	4.7	17.5	

TABLE XVIII

3.8X
(24" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	R_1 = 42.19 R_2 = 12.45	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	R_2 = 12.45 R_3 = 36.00	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 8.02 S_2 = 3.41 S_3 = 2.33
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.5 S_5 = 22.8
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO R_5 = 12.61	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	R_5 = 12.61 R_6 = 12.61	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	R_7 = 10.06 R_6 = 12.61	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	R_8 = 25.11 R_9 = 25.11	4.7	17.5	

TABLE XIX

4.3X
(12" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	R_1 = 42.19 R_2 = 12.45	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	R_2 = 12.45 R_3 = 36.00	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 18.7 S_2 = 3.41 S_3 = 2.33
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.5 S_5 = 22.8
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO R_5 = 12.61	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	R_5 = 12.61 R_6 = 12.61	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	R_7 = 10.06 R_6 = 12.61	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	R_8 = 25.11 R_9 = 25.11	4.7	17.5	

TABLE XX

4.3X
(16" WD)

Element	Glass	nd	νd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 15.56$ $S_2 = 3.41$ $S_3 = 2.33$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.5$ $S_5 = 22.8$
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO $R_5 = 12.61$	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	$R_5 = 12.61$ $R_6 = 12.61$	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	$R_7 = 10.06$ $R_6 = 12.61$	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	$R_8 = 25.11$ $R_9 = 25.11$	4.7	17.5	

TABLE XXI

4.3X
(24" WD)

Element	Glass	nd	νd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 13.13$ $S_2 = 3.41$ $S_3 = 2.33$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.5$ $S_5 = 22.8$
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO $R_5 = 12.61$	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	$R_5 = 12.61$ $R_6 = 12.61$	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	$R_7 = 10.06$ $R_6 = 12.61$	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	$R_8 = 25.11$ $R_9 = 25.11$	4.7	17.5	

TABLE XXII

4.8X
(12" WD)

Element	Glass	nd	vd	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	$R_1 = 42.19$ $R_2 = 12.45$	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	$R_2 = 12.45$ $R_3 = 36.00$	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_1 = 25.16$ $S_2 = 3.41$ $S_3 = 2.33$
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				$S_4 = 0.5$ $S_5 = 22.8$
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO $R_5 = 12.61$	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	$R_5 = 12.61$ $R_6 = 12.61$	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	$R_7 = 10.06$ $R_6 = 12.61$	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	$R_8 = 25.11$ $R_9 = 25.11$	4.7	17.5	

TABLE XXIII

4.8X
(16" WD)

Element	Glass	nd	*vd*	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	R_1 = 42.19 R_2 = 12.45	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	R_2 = 12.45 R_3 = 36.00	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 21.23 S_2 = 3.41 S_3 = 2.33
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.5 S_5 = 22.8
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO R_5 = 12.61	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	R_5 = 12.61 R_6 = 12.61	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	R_7 = 10.06 R_6 = 12.61	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	R_8 = 25.11 R_9 = 25.11	4.7	17.5	

TABLE XXIV

4.8X
(24" WD)

Element	Glass	nd	*v*d	Radius	Thickness	Diameter	Sep.
I	Ohara BAH 27	1.7015	41.2	R_1 = 42.19 R_2 = 12.45	3.5	13.4	
II	Ohara PBH6W	1.8052	25.4	R_2 = 12.45 R_3 = 36.00	1.5	13.4	
Prism A	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_1 = 18.22 S_2 = 3.41 S_3 = 2.33
Prism B	BAK4 LAK10	1.5688 1.7200	56.13 50.41				S_4 = 0.5 S_5 = 22.8
III	Ohara S-TIL2	1.5410	47.2	R_4 = PLANO R_5 = 12.61	3.0	12.0	
IV	Ohara PBH71	1.923	21.3	R_5 = 12.61 R_6 = 12.61	1.5	15.4	
V	SCHOTT BK7	1.5168	64.2	R_7 = 10.06 R_6 = 12.61	7.1	15.4	
VI	SCHOTT S-LAM2	1.744	44.8	R_8 = 25.11 R_9 = 25.11	4.7	17.5	

The invention described in the above detailed description is not intended to be limited to the specific form set forth herein, but, on the contrary, is intended to cover such alternative, modifications and equivalents as can reasonably be included within the spirit and scope of the appended claims.

WE CLAIM: